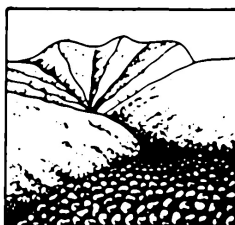


Труды Международной конференции

СЕЛЕВЫЕ ПОТОКИ: катастрофы, риск, прогноз, защита

Пятигорск, Россия, 22-29 сентября 2008 г.



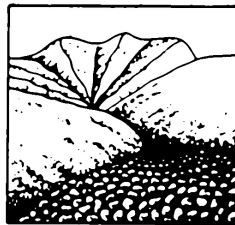
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При создании логотипа конференции использован рисунок из книги С.М. Флейшмана «Селевые потоки» (Москва: Географгиз, 1951, с. 51).
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Debris flow characteristic interpretation using image processing techniques

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Интерпретация характеристик селя с применением метода обработки изображений

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Характеристики селя, включая распределение размеров и траекторию пути гравийных частиц, исследованы с применением методов обработки изображений. Результаты могут быть использованы не только для поддержки системы предупреждения о селевом потоке, но и для фундаментального исследования селевого потока. Кроме того, интерпретация физических параметров по цифровым изображениям может заменить многие устройства обнаружения на участке полевых работ. Следовательно, становится возможным конструирование систем предупреждения с меньшим энергопотреблением и меньшего размера.

Characteristics of a debris flow, including size distribution and tracking trajectories of gravel, are explored by image processing techniques. The results can contribute not only to support of the debris flow warning systems, but also to fundamental research of debris flows. Moreover, interpretation of physical parameters from digital images may substitute for many detection devices at the field site. Consequently, less power and smaller dimensions are needed for a warning system.

1 Introduction

Nowadays, the CCD (charge couple device) monitoring devices are set up everywhere, such as public place, security service and hazardous controlled center. Unfortunately, most of the captured monitoring images were only used to show the outline situation at that time. There should be more valuable information which can be extracted from the digital images.

2 Notes on preparation

Though most size distribution curves were generally generated by sieved analyses by the sampled soil dug from the field site, the image processing techniques can be applied to interpret the surface size distribution curves of the gravels laid on the river bed objectively and widely. To explore the characteristic debris flow using image processing techniques, the installation of CCD at the field in advance is needed. In general, the CCD is not easy to install perpendicularly beyond the intermediate zone of the river in width. Consequently, the images will be frequently shot at an angle from river bank instead. If the gravels images captured with an angle of inclination θ , not only the diameter of soil particles distorted, but also the hiding effects within the gravels more or less appeared.

Fig. 1 shows the comparison between images captured with right angle and inclined angles. From the figure, one can see the shapes of gravels are twisted as the image shot without right angle. Thus, for the image captured with an incline angle, the distorted shape should be adjusted first. Moreover, to deal with the hiding effects between the particles, the shielded addenda scheme was then constructed. Two stretch connection, linear connection and circular connection were proposed to complement the missing parts of hiding gravels. Fig. 2 illustrates the sketch of shielded addendum. As shown in the figure, the linear connection is to join the two terminal points together with a straight line; similarly, the circular stretch connection is to draw a circle through the two terminal points.

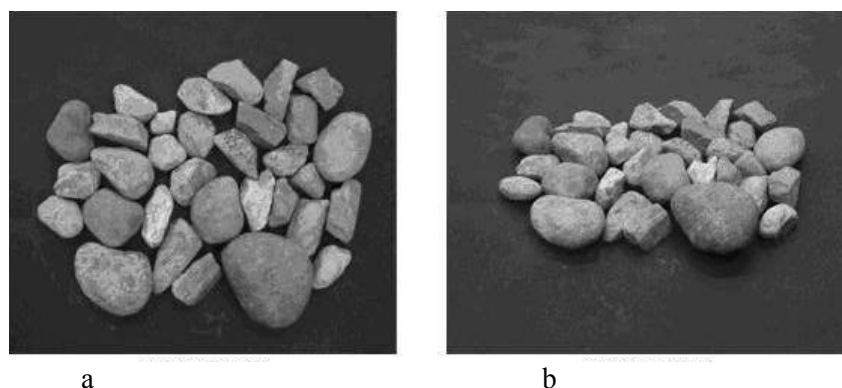


Fig.1. The comparison between images captured with right angle and inclined angles: a – gravel image (top view); b – gravel image captured with $\theta=40^\circ$.

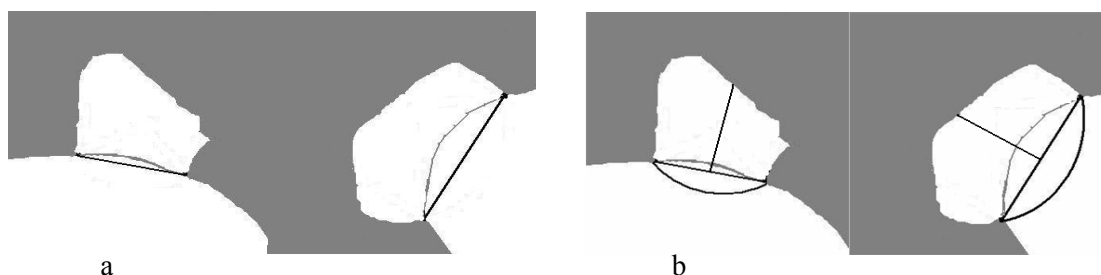


Fig. 2. Sketch of shielded addendum: a – shielded addendum by linear stretch connection, b – shielded addendum by circular stretch connection.

3 Discussion

3.1 Surface size distribution

Due to the difficulty of installing the CCD camera beyond the river bed perpendicularly, an angle of depression ($\theta=40^\circ$) of CCD based on the feasibility of recognition was chosen. As mentioned above, the tilted-shooting will cause images distorted and originate with hiding effect within gravels. The Indoor tests were accordingly conducted to simulate the grain size distribution in this study. By using image processing techniques, the shape of gravels image by tilted-shooting were adjusted. The adjusted grain image in comparison to top-view image is shown in Fig.3. The figure indicates most of gravels recover their original top-view shapes and relative allocation. For instance, the shape of gravel A and gravel B labeled in the image are almost the same, but there still has a hiding effect problem left, such as gravel C and gravel D.

Two shielded addendum method, linear connection and circular stretch connection, were proposed to deal with the hiding effect. The shielded addendum was carried out for each specific gravels. The shielded addendum method having done, the representative diameters for gravels can be estimated by a geometric diameter $D_g (= (L \times S)^{1/2})$, in which, L and S is the longest and shortest axis length of the gravel respectively. The comparison with various size

distribution analyses is shown in Fig. 4. From the figure, the size distribution curve derived from image captured with $\theta=40^\circ$ has significant deviation from the curve photographed vertically. Though the curve with angle adjusted correction has a better performance in comparison with the original one, the curve corrected by both angle adjusted and circular shielded addendum will lead to a more superior performance.

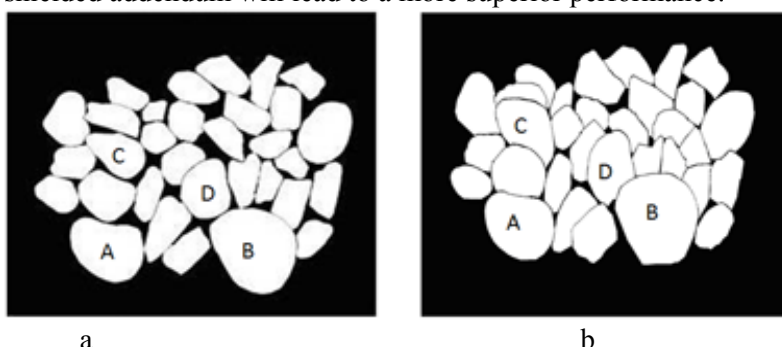


Fig. 3. The adjusted grain image in comparison to top-view image: a – original image ($\theta=90^\circ$), b – adjusted image ($\theta=40^\circ$).

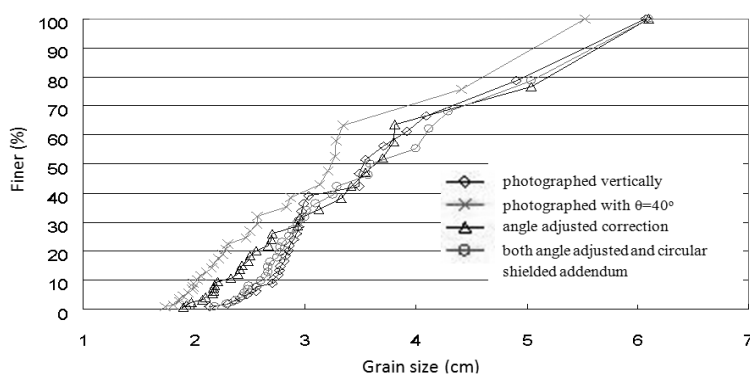


Fig. 4. The comparison with various size distribution analyses

Consequently, the median diameter D_{50} and the geometric standard deviation σ_g ($= (D_{84.1}/D_{15.9})^{0.5}$) of the size distribution can be determined. Results of size distribution analyses are listed in the Table 1. The results indicate the error of D_{50} (%) and is around 1.41% as both angle adjusted correct and circular shielded addendum were completed. The proposed image processing techniques are in reasonably good agreement with field data.

Table 1. Results of size distribution analyses by using image processing techniques.

| | | D_{50} | ϵ_{D50} (%) | σ_g | ϵ_{σ_g} (%) |
|-----------------------------|------------------------------|----------|----------------------|------------|---------------------------|
| sieved analyses | Field data | 3.54 | - | 1.36 | - |
| | Image with right angle | 3.53 | -0.28 | 1.37 | 0.74 |
| image processing techniques | Image with $\theta=40^\circ$ | 3.23 | -8.76 | 1.48 | 8.82 |
| | Angle adjusted correct only | 3.69 | 4.24 | 1.47 | 8.09 |
| | Linear shielded addendum** | 3.65 | 3.11 | 1.43 | 5.15 |
| | Circular shielded addendum** | 3.59 | 1.41 | 1.40 | 2.94 |

*: ϵ indicate the error;

** : 'Angle adjusted correction' performed in advance.

3.2 Trajectory tracking of gravels and their velocity

A series of indoor experiments were conducted to verify the feasibility of tracking the trajectory of specific surface gravels by using image processing techniques. The bed slope of indoor flume was set to 30° . Gravels groups with various sizes were placed on the smooth flume bed as shown in Fig. 5a.

The image captured from CCD should be segmented into the binary image in advance. To aim on the specific larger surface gravels and to neglect the smaller ones, a threshold value

that slightly greater than the global mean value was suggested to segment image. As shown in the Fig. 5b, one can see the suggested higher threshold value may segment the successive images well. The median filter, a noise-removal method, is necessarily used before image segmentations. After the median filter treatment, the edges of fine gravels are no longer significant, so that the fine gravels can be removed effectively.

After that, the chosen gravels segmented by image processing techniques were sorted and numbered. When gravels immigrate forward downstream, the ‘direction of movement’ and the ‘nearest neighbour’ schemes were applied to judge whether the two successive recognized similar particles are the same one. From Fig. 5c, the tracking trajectories of specific gravels have correspondence with actual gravels trajectories.

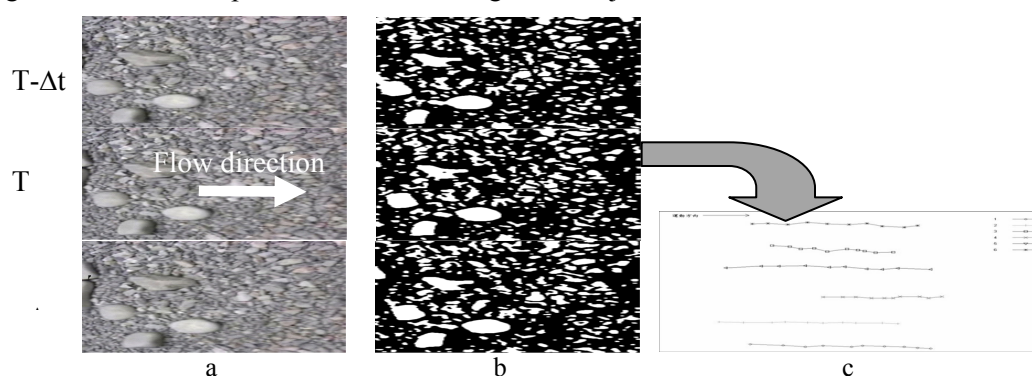


Fig. 5. A successive segmentation and the trajectory of gravel tracking: a - original image, b - binary image, c - the trajectories of specific gravels.

Referring to the trajectories, shooting angle and elevation of CCD, the trajectory velocity can be estimated by image processing techniques. The results of the trajectory velocity derived by image processing techniques are listed in Table 2. It can be shown that the estimated velocities for various gravels are in reasonably good agreement with the actual velocities.

Table 2. Results of the trajectory velocity derived by image processing techniques

| Gravel No. | Estimated velocity, m/s | Actual velocity, m/s | Error (%) |
|------------|-------------------------|----------------------|-----------|
| 1 | 2.48 | 2.40 | 3.33 |
| 2 | 2.24 | 2.35 | 3.83 |
| 3 | 2.25 | 2.31 | 2.60 |
| 4 | 2.36 | 2.23 | 5.83 |
| 5 | 2.47 | 2.41 | 2.49 |
| 6 | 2.52 | 2.43 | 3.71 |

4 Results

With angle adjusting correction and shielded addendum, both the median diameter and geometric standard deviation of the estimated grain size distribution using image processing techniques are physically correct and acceptable.

This study also tracks the debris migration. The image segmentation was firstly discussed and the debris migration was then tracking. The discrepancy between estimated velocity derived from the trajectory and actual velocity is about 3.63%. They are in reasonably good agreement.

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